

#### DISCUSSION

##### Introduction

The Stellwagen Bank National Marine Sanctuary Mapping Project is a cooperative effort of the U.S. Geological Survey and the National Oceanic and Atmospheric Administration, with support from the University of New Brunswick and the Canadian Hydrographic Service. The multibeam echo sounder survey was conducted on four cruises over a two-year period from the fall of 1994 to the fall of 1996. This map shows one of a series of 18 quadrangles (see location map) in which sea floor depth information is depicted in sun-illuminated (or shaded relief) view at a scale of 1:25,000, with topographic contours superimposed in blue. The image shown here uses a sun elevation angle of 45 degrees above the horizon from an azimuth of 250 degrees and a vertical exaggeration of four times. In effect, topographic relief is enhanced by halving the sun illuminate the sea floor from a position 10 degrees west of north, so that shadows are cast on the southern flanks of seafloor features. Some features in the images are artifacts of data collection. They are especially noticeable where the seafloor is smooth, and they include small high and low and unusual-looking features and patterns that are oriented parallel or perpendicular to survey tracklines. For a depiction of the topographic contours alone, and for an explanation of survey and topographic data-processing methods, see the companion map by Valentine and others (1997). Topographic contour maps of all 18 quadrangles in the map series are available on a CD-ROM in EPS, PS, Arc export, and PDF file formats (Valentine and others, 1998). Blank areas represent places where no data exist.

##### Regional seabed features

The major topographic features depicted in the map series were formed by glacial processes. In broad terms, these features are interpreted here to represent a geologic history that developed in several stages. Ice containing rock debris moved across the region, sculpting its surface and depositing sediment to form the large basins, banks, ridges, and valleys. Many other features observed here represent the later stages of degradation. They are the result of processes at work when much of the area was covered by stationary retreating ice, and when at the same time small valley glaciers and ice falls were active in and near areas of high topographic relief. The sea towards the region formerly occupied by ice, and seabed features were partly eroded and some new sedimentary deposits formed. Today, the sea floor is modified mainly by strong southwesterly-flowing bottom currents caused by storm winds from the northeast. These currents erode sediments from the shallow banks and transport them into the basins. With time, the banks affected by these currents become coarse, as sand and mud are removed and gravel remains, and the western flanks of the banks, as well as adjacent basins, are built up by deposits of mud and sand.

##### Quadrangle 4 features

Much of Quadrangle 4 lies in the southern part of Stellwagen Basin, where the sea floor of relatively smooth mud slopes southward through water depths of 45 to 95 m. Three large elongate banks are present in the basin. Their length ranges from 4.5 to 6.2 km, their tops lie in water depths of 55 to 70 m, and they have a relief of 15 to 30 m. The surfaces of the banks are covered with sand and gravel, including boulder piles and ridges, and a thin veneer of mud. The internal composition of the banks is unknown. Their north-south elongate shape suggests formation by glacial processes that eroded surrounding low-relief sand and rock during ice movement toward the southeast and that further modified the banks during later melting of the ice. The bank in the northeast corner of the quadrangle (42°12.7' N, 70°26.5' W) also lies partly in the adjacent Quadrangle 7 to the north (Valentine and others, 1998). It has a subcylindrical shape and a relatively flat surface. Another bank is located in the south-central part of the quadrangle (42°15' N, 70°29' W). It is long and narrow, and its western flank has been eroded into two separate embayments. The third bank lies along the eastern edge of the quadrangle (42°12' N) and is more eroded than the other two; it extends southward into the adjacent Quadrangle 5 (Valentine and others, 1998). A small, low hill, located near the northeastern edge of the quadrangle (42°17.9' N, 70°25.4' W), has a relief of only a few meters and possibly is the eroded remnant of a bank. Its surface, at 55 m water depth, is covered with gravel and a veneer of sandy mud. West and south of this feature, along the western edge of the quadrangle (42°16.8' to 42°18.3' N) at 50 to 55 m water depth, scattered exposures of coarse-grained sand are partly covered with deposits of fine-grained sand. The edges of the fine layers where they bound the coarse exposures, are curved and sharply defined, as if formed by bottom currents. It is possible that the coarse deposits have been exposed by bottom currents that have eroded the overlying fine layer. Similar features are present in the adjacent Quadrangle 1 to the south (Valentine and others, 2000).

The southwestern part of the quadrangle is a complex of long, southward-trending gravel banks that are separated by elongate basins covered with sand and muddy sand. The orientation of these features parallels the movement direction of glacial ice. Similar features are present in Quadrangle 1. The banks lie at 30 to 35 m water depth and have a relief of 5 to 10 m. Elongate piles and ridges of boulders and gravel, which have a relief of less than 5 m, are present on the banks. These features resemble coarse sand and gravel deposited by moving water within extensive, glacial ice and moraine deposits of rock debris piled up at the forward edges of moving ice. Boulders are present on the bank tops and flanks (42°15.3' N, 70°34' W); pebbles and mudstones are located on the southwestern ends of the banks and are oriented northward across the regional grain (42°13.3' N, 70°32.1' W; 42°12.2' N, 70°32.7' W). The gravel banks are, in places, partly covered with a thin veneer of sand. Shallow, irregularly shaped depressions in the sea floor outline

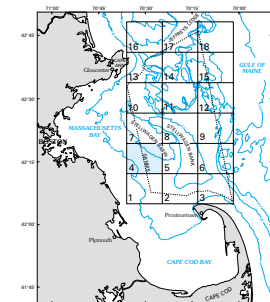
the former locations of large masses of melting glacial ice (42°14.3' N, 70°33.3' W). The basins that lie between the gravel banks are covered with sand and gravel around their margins and with muddy sand in their deepest parts (35 to 40 m). Sand and gravel deposits that cover the southwestern flanks of two gravel banks (42°12.6' N, 70°31.1' W; 42°13.0' N, 70°30.9' W) display southeast-trending grooves. Some of the grooves may be the result of gouging by icebergs that drifted southward from ice located on the banks; other grooves may be bedforms created by modern storm currents. The grooves are up to 50 m wide and 1.5 m long, are less than 5 m deep, and do not appear in water depths greater than 35 to 40 m.

A large lobe of sediment (42°12' N, 70°30' W) extends southeast from the gravel banks into Stellwagen Basin. This feature has a relief of several meters along its southern margin, and its surface composition varies from muddy sand in the west to sandy mud with increasing water depth to the east. In the northeastern part of the quadrangle, the smooth, almost flat mud floor of Stellwagen Basin is interrupted by a shallow depression that is irregular in outline and that contains small mounds (42°17.3' N, 70°34.5' W). The depression is 600 m long. Observations in Quadrangles 7 and 8 (Valentine and others, 1999c) have shown similar mounds to be patches of gravel, including boulders, that are frequented by groundfish. Boulders and smaller gravel have been observed in the bottom of pits in the mud in which fish are present. The depressions are interpreted to have been formed by the scouring action of groundfish that have exposed the gravel habitat and prevented its burial by basin mud.

##### REFERENCES CITED

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- Valentine, P.C., Baker, J.L., Unger, T.S., and Polloni, C., 1998, Sea floor topographic map and perspective view imagery of Quadrangles 1-18, Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts. U.S. Geological Survey Open-File Report 98-138, 1 CD-ROM.
- Valentine, P.C., Baker, J.L., and Unger, T.S., 1999a, Sun-illuminated sea floor topography of Quadrangle 5 in the Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts. U.S. Geological Survey Geologic Investigations Series Map I-2705, scale 1:25,000.
- , 1999b, Sun-illuminated sea floor topography of Quadrangle 7 in the Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts. U.S. Geological Survey Geologic Investigations Series Map I-2707, scale 1:25,000.
- , 2000, Sun-illuminated sea floor topography of Quadrangle 1 in the Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts. U.S. Geological Survey Geologic Investigations Series Map I-2701, scale 1:25,000.

Valentine, P.C., Unger, T.S., and Baker, J.L., 1999c, Sun-illuminated sea floor topography of Quadrangle 8 in the Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts. U.S. Geological Survey Geologic Investigations Series Map I-2708, scale 1:25,000.



Location map outlining the 18 quadrangles in this series. Quadrangle 4 shown in blue. Stellwagen Bank National Marine Sanctuary (SBNMS) boundary indicated by dashed line. Bathymetric contours in meters.

## SUN-ILLUMINATED SEA FLOOR TOPOGRAPHY OF QUADRANGLE 4 IN THE STELLWAGEN BANK NATIONAL MARINE SANCTUARY OFF BOSTON, MASSACHUSETTS

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